Fishery Data Series No. 00-38

Abundance and Composition of Arctic Grayling in the Delta Clearwater River, 1999

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Alaska Department of Fish and Game

Division of Sport Fish

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
ounce	oz
pound	lb
quart	qt
yard	yd

Spell out acre and ton.

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s

Spell out year, month, and week.

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
And	&
At	@
Compass directions:	
East	E
North	N
South	S
West	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
id est (that is)	i.e.,
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
Trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	F, t, χ^2, etc.
confidence interval	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
standard length	SL
total length	TL
variance	Var

FISHERY DATA SERIES NO. 99-38

ABUNDANCE AND COMPOSITION OF ARCTIC GRAYLING IN THE DELTA CLEARWATER RIVER, 1999

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ABSTRACT

A mark-recapture experiment was conducted along the lower 14 miles of the Delta Clearwater River during the middle of July 1999 to estimate abundance and composition of Arctic grayling *Thymallus arcticus*. Hook-and-line methods using jigs, flies, and spinners as terminal gear captured 2,028 fish. Estimated abundance of Arctic grayling ≥ 240 mm FL was 6,977 fish (SE = 401). Quality-sized and larger fish (≥ 270 mm FL) predominated (96%) the sample. Age-5 fish were fully recruited to the sampling gear similar to previous years. Age-5 and age-6 fish composed 25% and 27% (SE 1%) of the population ≥ 240 mm FL. Jig and fly marked fish had similar capture probabilities; therefore, they were pooled for the abundance estimate.

Key words: Arctic grayling, *Thymallus arcticus,* abundance, age composition, size composition, gear shyness, hook shyness, hook and line, capture probability, Delta Clearwater River, Alaska.

INTRODUCTION

The Delta Clearwater River (DCR) is a 21 mi spring-fed system located 110 mi southeast of Fairbanks and 14 mi northeast of Delta Junction in the middle Tanana River drainage (Figure 1). It is the largest and most accessible of a number of spring-fed systems that begin in alluvial deposits on the south side of the drainage. The larger of these systems provide quality summer feeding habitat for Arctic grayling; however, these fish neither spawn nor overwinter in these systems (Reed 1961; Tack 1980; Ridder 1991). The DCR Arctic grayling fishery is unique among the major road accessible fisheries in the drainage because it is composed of fish that spawn in at least eight different systems (Ridder 1998a). Arctic grayling movement into the DCR begins in April with juvenile fish, followed by adults, and continues into June. Movement out of DCR begins in August and is completed by December.

Since becoming road accessible in 1953, the DCR has offered a small but productive and popular Arctic grayling fishery, which is known for its high catch rates, large Arctic grayling, and pristine water quality. In the past, harvest of Arctic grayling was predominantly age-5 and older fish. Prior to 1987, average annual harvests of 5,700 fish ranked the DCR in the top five Arctic grayling fisheries in the Tanana drainage (Table 1).

Drainage-wide declines in harvest and abundance indices in the middle 1980s led to restrictive regulations for the DCR and other drainage fisheries in 1987. These regulations included a catch and release season from 1 April to the first Saturday in June, a 305 mm TL minimum-size limit, a no-bait restriction, and five-fish daily bag and possession limit (limits were 10 fish daily and 20 fish in possession prior to 1977 and five and 10 through 1986). From 1987 through 1994, average annual harvest declined to 1,800 fish (Table 1). Results from CAGEAN modeling of the fishery from 1977-1990 and other studies from 1995 and 1996 led to further restrictions to the fishery in 1995 and 1997. A two-fish bag and possession limit imposed in July of 1995 through 1996 lowered average annual harvest to 969 fish. The fishery became catch and release in June of 1997.

Two programs to enhance the Arctic grayling fishery in the DCR ran from 1974 through 1979 and 1983 through 1987. Through these enhancement programs, the river was stocked with 567,786 Arctic grayling (Appendix A1). The majority, 400,000 fish, was stocked as fry in 1974 and 1975. These stockings were considered failures and subsequent stockings, 164,355 fish, were of fish reared for three months in shallow ponds at Clear Hatchery. Limited stocking of

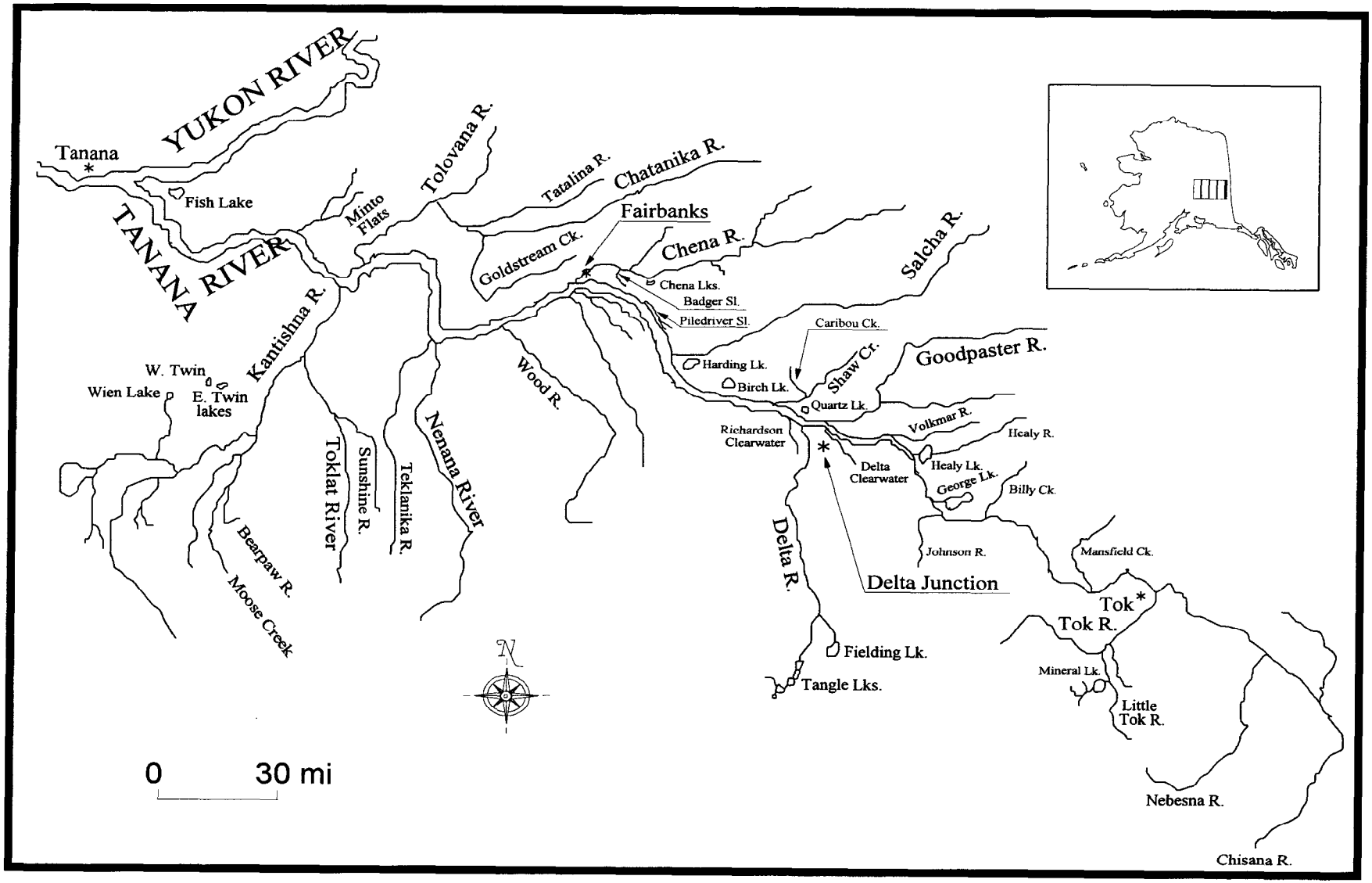

Figure 1.-The Tanana River drainage.

Table 1.-Anglers, angler days, harvest, and catch of Arctic grayling from the Delta Clearwater River, 1977-1999.

Year	Anglers[a]	Angler Days[a]	Harvest	Catch
1977	na[b]	6,881	6,118	na
1978	Na	7,210	7,657	na
1979	Na	8,398	6,492	na
1980	Na	4,240	5,680	na
1981	Na	4,673	7,362	na
1982	Na	4,231	4,779	na
1983	Na	5,867	6,546	na
1984	2,024	5,139	4,193	na
1985	2,947	8,722	5,809	na
1986	3,693	10,137	2,343	na
1987[c]	3,068	5,397	2,005	na
1988[c]	2,413	5,184	2,910	na
1989[c]	2,845	5,368	3,016	na
1990[c]	2,498	4,853	1,772	12,424
1991[c]	3,171	5,594	2,165	7,998
1992[c]	1,770	3,756	797	6,086
1993[c]	1,491	4,909	437	5,712
1994[c]	2,100	3,984	1,411	9,306
1995[c,d]	2,927	6,261	926	5,974
1996[d]	2,286	3,424	1,012	8,978
1997[e]	1,680	2,161	54	6,089
1998	1,548	3,415	0	15,990
		Averages		
1978-1998	2,524	5,636	3,495	7,702
1977-1986	2,888	6,550	5,698	Na
1987-1994[c]	2,420	4,881	1,814	8,305
1995-1996[d]	2,607	4,843	969	7,476

Data from: Mills 1978-1994 and Howe et al. 1995-1999

[a] Anglers and days fished represents effort on all species.

[b] na = not available.

[c] Regulations for 1987 through June 1995 changed from no closed season and a five fish bag and a 10 fish possession limit to catch-and-release fishing from 1 April until the first Saturday in June, a 305 mm (12 inch) minimum length limit; a five fish bag and possession limit; and, a restriction of terminal gear to unbaited artificial lures.

[d] The daily bag and possession limits were reduced from five fish to two fish in July 1995 through 1996.

[e] In June 1997, the Delta Clearwater River and its tributaries were closed to possession of Arctic grayling from 1 January through 31 December.

age-1 fish also occurred (n = 3,431). Between 1978 and 1990, stocked fish[1] accounted for 2 to 24% of the harvest averaging 13% (Ridder 1985; Ridder *Unpublished*). Unlike wild fish, stocked fish were predominantly harvested between ages 2 and 4 due to a larger size at age. Stocked fish ≥ age-5 averaged 4% of all fish harvested and 10% of fish age-5 and older in the harvest.

Stock assessments on the DCR have historically been monitoring programs centered on creel surveys, age and length sampling, and relative abundance indices (the catch rate from one downstream pass of an electrofishing boat; Peckham and Ridder 1979, Ridder 1985). Even though these assessments may have detected population trends, they did not yield estimates of abundance, recruitment, survival and exploitation from which to actively manage the fishery. CAGEAN modeling (Clark and Ridder 1994) provided the first look into the dynamics of the DCR population. A study was conducted from 1995 through 1997 to investigate the major assumption of geographic closure needed for use of the CAGEAN model (Ridder 1998a). The study determined that the DCR population could be classified as a summer stock unit due to the high level of fidelity (98%, SE = 3%; Ridder 1998a) to the DCR each summer. Studies estimating the abundance of Arctic grayling in the DCR using Peterson mark-recapture methodology were conducted in 1996, 1997, and 1998 to document the population's response to regulatory changes (Ridder 1998b). This study continued this documentation and utilized similar methodology.

Specific objectives of Project F-10-15, Job R-3-2(c) were to estimate:

1. abundance of Arctic grayling (≥150 mm FL)[2] in the lower 17 mi of the Delta Clearwater River, such that this estimate is within 25% of the true abundance 95% of the time;

2. age composition of the Arctic grayling (≥150 mm FL)[2] in the lower 17 mi of the Delta Clearwater River, such that all proportions are within 5 percentage points of the true proportions 95% of the time; and,

3. length composition of the Arctic grayling (≥150 mm FL)[2] in the lower 17 mi of the Delta Clearwater River, such that all proportions are within 5 percentage points of the true proportions 95% of the time.

The study also investigated differences between capture probabilities of fly- and jig-marked fish. Age and size composition of all captured fish from 1996 through 1999, hook-and-line catch rates for 1999, and a summary of estimates of abundance and recruitment from 1977 through 1999 are given in Appendix A to provide comparisons with historical data.

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[1] Stocked fish were discriminated from wild fish by physical characteristics of fin clip (for brood years 1983-86) and high circular counts on scales from brood years 1975-1979; (Ridder 1985).

[2] Due to the length of the smallest recaptured fish, abundance and composition was estimated for fish ≥ 240 instead of ≥ 150 mm FL.

METHODS

Arctic grayling were historically present up to mile 17 of the Sawmill Creek fork of the DCR while few, if any, Arctic grayling have inhabited the north fork of the DCR (Peckham and Ridder 1979; Figure 2). However, information from creel interviews and intermittent surveys by Alaska Department of Fish and Game (ADF&G) personnel indicates that few grayling have been present in the Sawmill Creek fork since the late 1980s through 1995 (Ridder *Unpublished*). Less than 10 Arctic grayling in 1996, 30 in 1997, and 50 in 1998 were observed in the one-mile section downstream of mile 15. Given the absence of fish, the upper boundary for the mark-recapture experiment was set at mile 14 for this experiment similar to prior years (Ridder 1998b; Ridder 1999). The lower boundary was set at mile 1 where a side slough of the silt-laden Tanana River enters the river during the summer and causes the lower river to become turbid and not fishable.

The study area was divided in two different ways for comparison to historical information and for investigating bias. For comparisons to historical data, catch and effort data that is presented in the appendices are stratified into two sections at mile 8. Above mile 8, the river is distinctly more shallow and narrow than below. Mile 8 is also the location of the only state campground and public boat launch on the river. Creel surveys from 1976 through 1990 have used the boat launch as a boundary in recording angler use, preference, catch rates, and age and length compositions of the harvest. For investigating bias due to movement and capture probabilities, the river was divided into three sections: Section 1 was miles 2 – 5; Section 2 was miles 6 – 10 and; Section 3 was miles 11 – 14.

Two 5-d sampling events were conducted in 1999. The two events occurred between 12 and 23 July, were separated by a 2-d hiatus, and composed the two-event Peterson mark-recapture experiment. During each event, five two-man crews were positioned along the study area beginning at mile 14. Crews were made up of volunteer and ADF&G personnel. Each crew proceeded downstream fishing each pool and run in a systematic manner usually covering less than a mile per day. Hook-and-line was used to capture fish primarily with dry flies, white crappie "mini" jigs, and to a much lesser extent, small spinners. Crews selected terminal gear at their discretion. All captured Arctic grayling were processed immediately or soon after capture, marked with a Floy FD 94 anchor tag, given a partial fin-clip, and then released at, or very near the capture site. Data on date, location, crew, tackle type (fly, jig, or spinner), length, scale samples, old finclips, tag number, tag color, recapture status, and mortality were recorded. Data were recorded on scale sample envelopes or field forms and later transferred to mark sense forms. These were transformed into an electronic (ASCII) data file for analysis and archival (Appendix B1).

Estimates of abundance were derived for three components of the population. The first component was estimated abundance for fish $\geq$ 240 mm FL. This component was further stratified by gear type to investigate hook shyness. The second component was necessary for comparisons to historical sample and harvest data (fish $\geq$ 270 mm FL). This length is approximately equal to the minimum length for harvest in the fishery (305 mm TL) and approximates the adult component of the population (Clark 1992). The third component was for age-5 and older fish. This component was used for CAGEAN estimates and was based on the age at full recruitment to the population and fishery (Clark and Ridder 1994). Estimates of the latter two components were estimated proportionately from the first component.

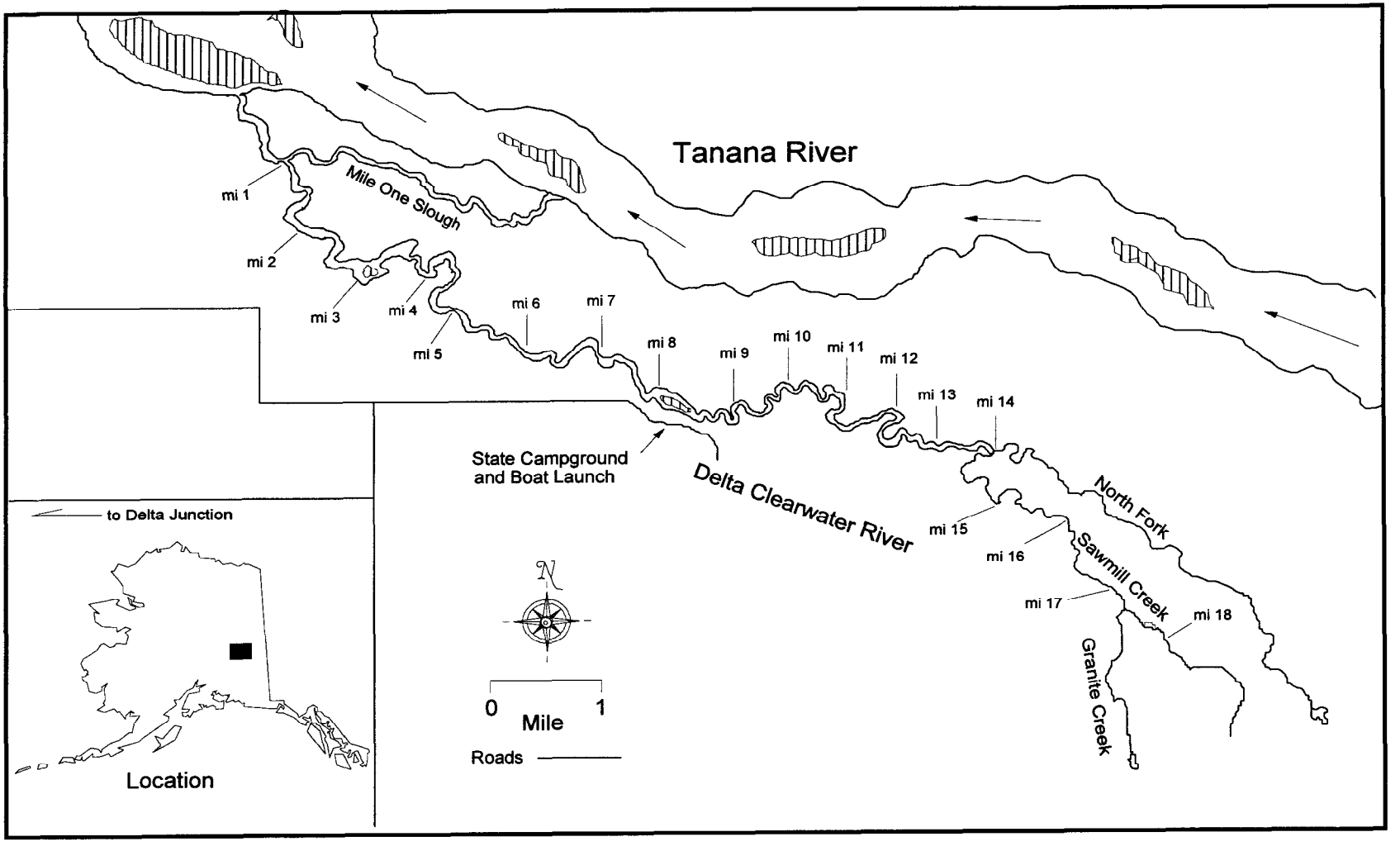


Figure 2.-The Delta Clearwater River.

ESTIMATION OF ABUNDANCE

The mark-recapture experiment was designed to satisfy the assumptions of a Petersen mark-recapture experiment (Seber 1982). These assumptions were that:

1. the population was closed (no change in the number or composition of Arctic grayling in the population during the experiment);
2. all Arctic grayling had the same probability of capture in the first sample or in the second sample, or marked and unmarked Arctic grayling mixed uniformly between the first and second samples;
3. marking of Arctic grayling did not affect their probability of capture in the second sample;
4. Arctic grayling did not lose their mark between sampling events; and,
5. all marked Arctic grayling were reported when recovered in the second sample.

Testing of Assumptions

Assumption 1 was assumed because of the size of the study area, the short duration of the experiment (the middle two weeks of July), and results from other studies. Tack (1973) reported little movement of Arctic grayling during the summer feeding period during a six-month study of a 150-mi section of the Goodpaster River. In a two-year radiotelemetry study of adult-sized fish (Ridder 1998a; Ridder *Unpublished*), post spawning movements to the DCR were completed by 5 June for 37 of 39 Arctic grayling that over summered in the DCR and by 23 June for 38 of the 39 fish. In the same study, movement out of the DCR was not detected until 6 August in 1995 and 15 August in 1996. Conducting this experiment in the middle of July and using a large section of the river as the study area reduced the probability of fish entering or leaving the study area between sampling events. The short duration of the experiment reduced the likelihood that mortality or recruitment due to growth occurred between sampling events.

The validity of assumptions 2 and 3 was tested by comparing recapture rates and movements of fish between events with tests of consistency designed to detect unequal catchability by area and by size of fish (Seber 1982; Bernard and Hansen 1992). Distinctive and permanent marking and rigorous examination of all captured fish ensured the validity of assumptions 4 and 5.

Tests indicated that assumption 2 was not valid for this experiment due to unequal mixing of fish, unequal catchability of fish, and non-uniform sampling during both events. By default, the Darroch estimator of abundance was used in place of the Petersen since this estimator does not require the validity of assumption 2 (Darroch 1961).

Calculation of Abundance

Maximum likelihood (ML) estimates of the Darroch likelihood were found by a direct searching algorithm (M. Wallendorf, Alaska Department of Fish and Game, Fairbanks, personal communication). The ML estimator required that for each tagging location, the movement probabilities were restricted to sum to 1 (consistent with the closure assumption). The objective function for the natural log of the Darroch likelihood was:

$$L = \sum_i \{(a_i - c_{i\cdot}) \log[1 - \sum_j \Theta_{ij} p_j]\} + \sum_i \sum_j c_{ij} \log(\Theta_{ij} p_j), \quad (1)$$

where:

a_i = number of fish tagged at location i;

c_{ij} = number tagged fish from location i recaptured at location j;

$c_{i\cdot} = \sum_j c_{ij}$;

p_j = second sample capture probability for location j; and,

Θ_{ij} = probability of movement from tagging location i to recapture location j.

The estimate of untagged fish in the jth location of the second sample was:

$$\tilde{n}_j = b_j / \hat{p}_j \tag{2}$$

where b_j was the number of untagged fish caught in the second sample.

Total abundance was:

$$\tilde{N} = \sum_j \tilde{n}_j + \sum_i a_i \,. \tag{3}$$

The covariance matrix for the capture probabilities and movement probabilities were estimated using the observed information matrix. The variance for the abundance estimate was then approximated using the delta method (Seber 1982).

ESTIMATION OF AGE AND SIZE COMPOSITION

For aging, scales were taken from the area approximately six scale rows above the lateral line just posterior to the insertion of the dorsal fin (W. Ridder *Unpublished*; Brown 1943). Scales were processed by wiping slime and dirt off each scale and mounting on gummed cards. The gum cards were used to make triacetate impressions of the scales (30 s at 137,895 kPa, at a temperature of 97°C). Ages were determined by counts of annuli from the triacetate impressions magnified to 40X with a microfiche reader. Criteria for determining annuli were when: 1) complete circuli cut over incomplete circuli; 2) clear areas or irregularities in circuli were present along the anterior and posterior fields; and, 3) regions of closely spaced circuli were followed by a region of widely spaced circuli (Kruse 1959). Age composition was described with proportions of the stock contained in each age class. Size composition of Arctic grayling was described with the incremental Relative Stock Density (RSD) indices of Gabelhouse (1984). The RSD categories of Gabelhouse are: "stock" (150 to 269 mm FL); "quality" (270 to 339 mm FL); "preferred" (340 to 449 mm FL); "memorable" (450 to 559 mm FL); and, "trophy" (greater than 559 mm FL).

From tests of assumptions 2 and 3, significant differences in capture probability by area were found. Differences in capture probability may bias estimates of age and size compositions. Age and size data were adjusted for these differences so that the age and size composition of Arctic grayling in the lower 14 mi of the Delta Clearwater River could be estimated. First, the proportions of fish by age class or size category were estimated for each stratum used in

estimation of abundance:

$$\hat{p}_{ik} = \frac{n_{ik}}{n_i} \tag{4}$$

where:

$\hat{p}_{ik}$ = the estimated proportion of fish in age or size category *k* that were sampled in stratum i;

n_{ik} = the number of fish sampled in age or size category *k* in stratum i; and,

n_i = the number of fish sampled in stratum i.

Variance of this proportion was estimated using the variance of a binomial. Next the abundance of each age class or size category was estimated from the proportions and abundance in each stratum:

$$\hat{N}_{ik} = \hat{p}_{ik}\hat{N}_i \tag{5}$$

where:

$\hat{N}_{ik}$ = the estimated abundance of age or size category *k* fish sampled in stratum *i*.

Variance of the abundance of each age or size category was estimated as a variance of the product of two independent variables (Goodman 1960):

$$\hat{V}[\hat{N}_k] = \hat{p}_k^2\hat{V}[\hat{N}] + \hat{N}^2\hat{V}[\hat{p}_k] - \hat{V}[\hat{N}]\hat{V}[\hat{p}_k]. \tag{6}$$

After calculating abundance at age or size in each stratum, the overall proportions were estimated by:

$$\hat{p}'_k = \sum_{i=1}^{s} \frac{\hat{N}_i}{\hat{N}_{ALL}}\hat{p}_{ik} \tag{7}$$

where:

$\hat{p}'_k$ = the estimated weighted proportion of Arctic grayling in the lower 14 river mi of the Delta Clearwater River that were age or size *k*.

Variance of the proportions were approximated with the delta method (see Seber 1982):

$$\hat{V}[\hat{p}'_k] \approx \sum_{i=1}^{s} \frac{(\hat{p}_{ik} - \hat{p}'_k)^2\,\hat{V}[\hat{N}_i]}{\hat{N}_{ALL}^{\,2}} + \sum_{i=1}^{s}\left(\frac{\hat{N}_i}{\hat{N}_{ALL}}\right)^2 \hat{V}[\hat{p}_{ik}]. \tag{8}$$

These estimated weighted proportions and variances by age and size were used as estimates of age and size compositions in the lower 14 mi of the Delta Clearwater River.

HOOK SHYNESS

Reactions of fish to capture methods can affect their subsequent recapture through either avoidance behavior (gear shyness) or attraction (gear happiness). In mark recapture experiments,

these reactions bias estimates. In this study, gear shyness to the capture method in general and, specifically, gear type (flies and jigs) was investigated with two sampling events. Probabilities of recapture for fish marked with flies and for fish marked with jigs were examined for differences.

RESULTS

In two sampling events in 1999, 2,028 Arctic grayling (≥ 150 mm FL) were captured with 572 angler-hours of effort (Table 2; Appendices A2 and A3). Angling effort by ten ADF&G personnel (57%) and nine volunteers (43%) was similar between events and resulted in an overall CPUE was 3.46 fish/h (Table 2; Appendices A2 through A5). Three percent of these fish (n = 56) were caught twice within the same event. Of the 1,971 fish that were unique to the events, 136 fish (6.9%) were recaptures of fish released in the first event and 420 fish (21.3%) were recaptures from other studies. Five fish died immediately during the sampling events. Although the smallest recaptured fish was 225 mm FL, the data set for estimating abundance was truncated to fish ≥ 240 mm to conform with previous abundance estimates (Table 2). Fish less than 240 mm FL (n = 24) accounted for only 1% of the unique catch from the two events.

HOOK SHYNESS

Hook shyness was investigated in fish greater than 240 mm FL to correspond to the assessed population. Of the 1,948 fish ≥ 240 mm FL caught with hook and line gear in 1999, 1,028 were caught with jigs, 886 with flies and 34 had unrecorded capture gear (Appendix A4). The ratio of jig caught fish to fly caught fish was dissimilar between events. Jig-caught fish were predominate in the first event (n_{jig} = 647 and n_{fly} = 411) and fly-caught fish were more numerous in the second event (n_{jig} = 381 and n_{fly} = 475; Appendix A4). However, there were no significant differences in recapture rates (R/M) between jig-and fly-marked fish when they were recaptured by both or either gear type (Table 3). Proportion of fish captured by gear type were not uniform along the study reach within events or between events (Appendix A7). Differences in the movements of jig- and fly-marked fish, however, were not detected (χ^2 = 1.57; df = 2; P = 0.46; Table 4).

ABUNDANCE

The mark recapture experiment for estimating abundance of Arctic grayling in the DCR consisted of two 5-d events within a two-week period. On average there was a 5-day hiatus between events for any given location on the river. During the first event, 12-16 July, 1,111 fish ≥ 240 mm FL were captured of which 39 fish were caught twice, 3 fish died and 1,069 unique fish were released alive with marks (Table 2). During the second event, 19-23 July, 894 fish ≥ 240 mm FL were captured with 17 fish caught twice, 2 fish killed and 135 fish recaptured from the first event (Table 2).

Size stratification was not necessary in the experiment since length composition was not significantly different between fish released in the first event and those fish recaptured from the first event (D = 0.10; P = 0.21; Figure 3). Tests of consistency by area, however, indicated that there was unequal mixing of fish, unequal catchability of fish, and non-uniform sampling during both events (Tables 5-7). Significant differences were found among the three areas in R/C ratios

Table 2.-Hours fished (effort), number of fish caught, unique, killed, ≥ 150 mm FL, ≥ 240 mm FL, and recaptured by event during the mark-recapture experiment, Delta Clearwater River, July 1999.

		Number of Fish					
Event	Effort	Caught	Unique	Killed	≥ 150 mm FL	≥ 240 mm FL	Recaps
1	288	1125	1087	3	1084	1069	---
2	284	903	889	2	---	---	136
Totals	572	2028	1976	5	1084	1069	136

Table 3.-Chi-square statistics, recapture rates, number marked, examined for marks, and recaptured by gear type for Arctic grayling ≥ 240 mm FL marked and captured in the Delta Clearwater River, July 1999.

Marking Gear[a]	M[b]	C[c]	R[d]	R/M	SE[R/M]	χ^2	p
Recaptured by All Gear Types							
All gear:	1,058	856	135	0.13	0.01		
Jig:	647	856	79	0.12	0.01	0.11	0.74
Fly:	411	856	53	0.13	0.02		
Recaptured by Jigs							
All gear:	1,058	381	61	0.06	0.01		
Jig:	647	381	42	0.06	0.01	1.62	0.20
Fly:	411	381	19	0.05	0.01		
Recaptured by Flies							
All gear:	1,058	475	71	0.07	0.01		
Jig:	647	475	37	0.06	0.01	2.62	0.11
Fly:	411	475	34	0.08	0.01		

[a] all data included is for catches in which gear type was recorded

[b] = number of marked fish released alive in first event.

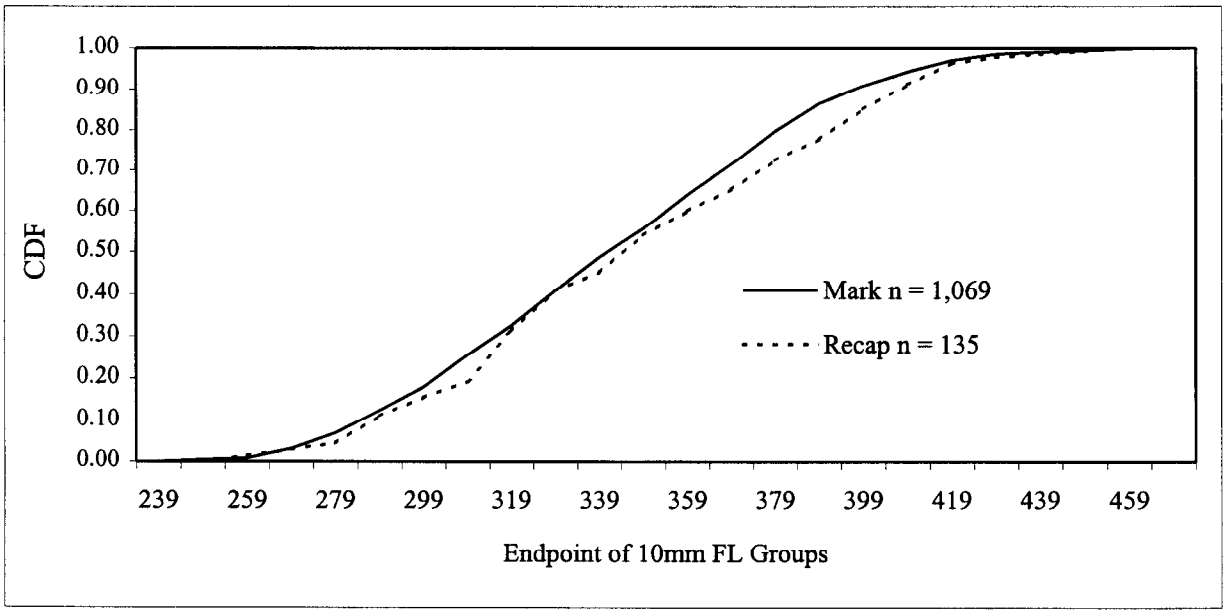
[c] C = number of fish examined in second event.

[d] R = number of marked fish from first event and recaptured in second event.

Table 4.-Number and proportion of Arctic grayling ≥ 240 mm FL recaptured by marking gear type, distance from marking location, and direction from marking location in the Delta Clearwater River, July 1999.

	All			Fly			Jig		
	n	p	SE	N	p	SE	N	p	SE
Miles Moved									
>-5	3	0.02	0.01	1	0.02	0.02	2	0.03	0.02
-2 - -5	9	0.07	0.02	5	0.10	0.02	3	0.04	0.02
-1 - -2	16	0.12	0.03	6	0.12	0.04	10	0.13	0.04
0	92	0.68	0.03	33	0.63	0.05	57	0.72	0.04
1 - 2	11	0.08	0.02	6	0.11	0.04	5	0.06	0.03
2 - 5	4	0.03	0.01	2	0.04	0.02	2	0.03	0.02
> 5	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
Total	135	1.00	---	54	1.00	---	79	1.00	---
Direction Moved[a]									
DS	28	0.21	0.05	12	0.23	0.05	15	0.19	0.04
NM	92	0.68	0.05	33	0.63	0.04	57	0.72	0.05
US	15	0.12	0.03	8	0.15	0.04	7	0.09	0.03
Total	135	1.00	---	53	1.00	---	79	1.00	---

[a] Direction moved: DS = downstream; NM = no movement; US = upstream.



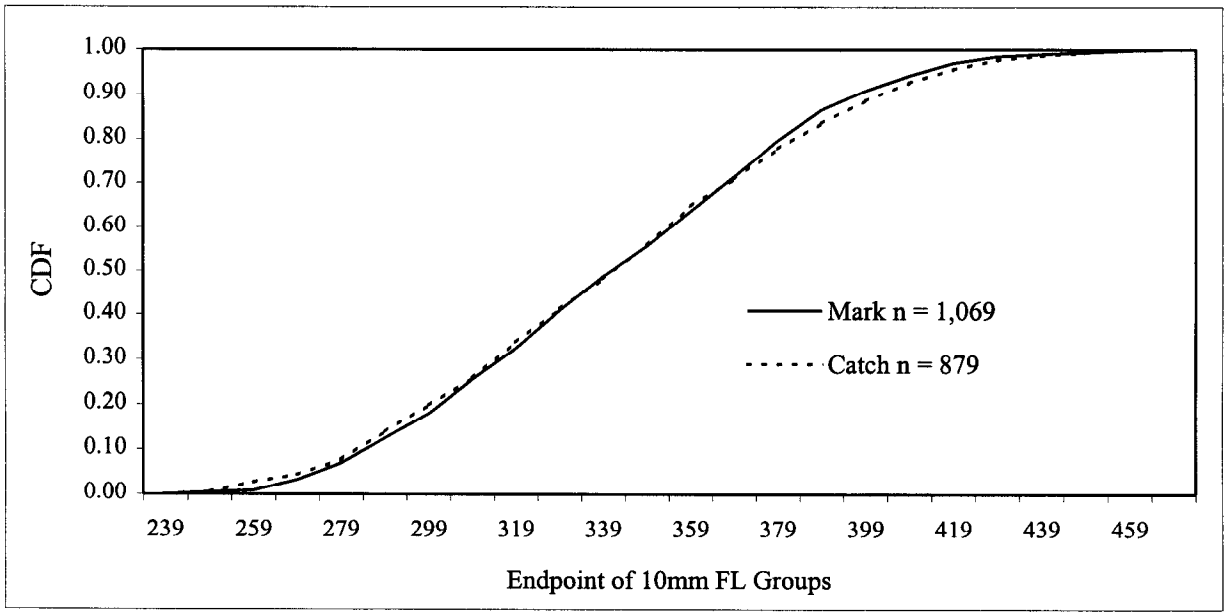


Figure 3.-Cumulative distribution functions (CDF) of 10 mm FL groups of Arctic grayling ≥ 240 mm FL marked, captured, and recaptured, Delta Clearwater River, July 1999.

Table 5.-Numbers of Arctic grayling marked in lower (miles 2-5), middle (miles 6-10) and upper (miles 11-14) areas and recovered in lower, middle and upper areas of the Delta Clearwater River, or not recovered, July 1999.

Marking	Recover History				
Area	Lower	Middle	Upper	Not Recovered	Total
Lower	39	3	0	381	423
Middle	10	22	2	261	295
Upper	3	4	53	292	351
Total	51	29	55	934	1,069

Table 6.-Numbers of marked Arctic grayling recovered and not recovered during the recapture event by lower (miles 2-5), middle (miles 6-10) and upper (miles 11-14) areas of the Delta Clearwater River, July 1999.

	Marking Area			
History	Lower	Middle	Upper	Total
Recovered	42	34	59	135
Not Recovered	381	261	292	936
Total	423	295	351	1,069

Table 7.-Numbers of marked and unmarked Arctic grayling captured during the recapture event by lower (miles 2-5), middle (miles 6-10) and upper (miles 11-14) areas of the Delta Clearwater River, July 1999.

	Capture Area			
Arctic Grayling	Lower	Middle	Upper	Total
Marked	51	29	55	135
Not Marked	225	253	266	744
Total	276	282	321	879

(χ^2 =8.4; df = 2; P = 0.01), R/M ratios (χ^2 = 8.7; df = 2; P = 0.01) and movement (χ^2 = 167.6; df = 6; P < 0.01). For this reason, the maximum likelihood (ML) estimates of the stratified model of Darroch (1961) were more appropriate for estimating abundance than the Petersen estimator. The Darroch estimate of Arctic grayling ≥ 240 mm in the lower 14 mi of the Delta Clearwater River was 6,977 (SE = 401; Table 8). Abundance for fish ≥ 270 mm FL was 6,684 fish (SE = 408; Table 9) and for fish age-5 and older was 6,250 fish (SE = 407; Table 10).

Size and Age Composition

The length of fish caught during the two events ranged from 168 mm FL to 462 mm FL. The length composition of fish ≥ 240 mm FL captured in each event was similar (D = 0.04; P = 0.44; Figure 4). Most fish caught in each event (95.3% and 94.5%) were greater than 270 mm FL.

Size composition of the July population (fish ≥ 240 mm) was estimated from pooled samples of all gear types from the first two events. Size selectivity was not detected in the second event (D = 0.06; P = 0.74) and size composition was similar between events (D = 0.04; P = 0.44) for all gear types combined (Figure 3). However, size compositions of fly and jig marked fish were dissimilar in the first event (D = 0.68; P = 0.00) and the second event (D = 0.15; P = < 0.01; Figure 5).

RSD estimates of the July abundance were biased by the truncation of the sample to fish ≥ 240 mm. This excluded the majority of the stock-sized category (150-269 mm FL). Also, no fish were captured in the trophy-sized category (≥ 560 mm). Abundance was estimated for three of five RSD categories. Estimated abundance of quality-sized and larger fish (≥ 270 mm FL) was 6,684 (SE = 211; Table 10). The bulk of the fish captured were within the preferred (340-449 mm) and memorable-size classes (450-559 mm; Table 9).

Age composition was estimated from samples taken during the second event. Ages ranged from age-3 to age-13 in the total sample (Appendix A8). Among fish ≥ 240 mm, age-5 and age-6 fish were represented in the greatest proportions (25% and 27%; SE = 1%; Table 10).

Movements

Among 135 fish with known release and recapture locations, 92 (68%) fish were recaptured within the same one-mile section in which they had been marked. Of the 43 fish which moved outside of the one-mile sampling areas in which marked, 28 fish moved downstream (Tables 4 and 11).

DISCUSSION

This study represents the third consecutive year in which sufficient numbers of Arctic grayling were marked and examined for marks to successfully estimate abundance of Arctic grayling in the DCR using mark-recapture techniques. Prior to this, large catches were difficult to obtain by sampling the harvest, electrofishing, trapping, or seining. The success this year and in the two previous years was a result of using hook-and-line methods and a large number of crewmembers. The probability of catching a fish in the DCR depends on many variables that cannot be held constant over the course of a study. Angling ability, choice of terminal gear, location of fishing, time of day, depth of the fish, and feeding patterns have influenced catches. These concerns were addressed over the past three years by soliciting experienced anglers, spreading daily effort

Table 8.-Number of fish marked, examined, recaptured during sampling, and estimated abundances with standard errors and coefficients of variation for Arctic grayling (≥ 240 mm FL) in three sections of the Delta Clearwater River, July 1999.

Section	River miles	Mark	Catch	Recap	N[a]	SE[N]	CV
Lower	2 – 5	423	276	42	2,910	270	9%
Middle	6 – 10	295	282	34	2,287	279	12%
Upper	11 - 14	351	321	59	1,780	100	6%
Total	2 - 14	1,069	744	135	6,977	401	6%

[a] N estimated with the stratified model of Darroch (1961).

Table 9-Relative Stock Density (RSD) indices of Arctic grayling sampled and the abundance and standard errors for fish ≥ 240 mm FL, Delta Clearwater River, July 1999.

Category	Length (mm FL)	n	RSD[b]	SE[RSD]	N	SE[N]
Stock	150 – 269[a]	68	0.04	0.01	---	---
Quality	270 - 339	812	0.48	0.02	3,357	148
Preferred	340 - 449	915	0.47	0.02	3,287	150
Memorable	450 – 559	12	0.01	<0.01	40	15
Trophy	≥560	0	---	---	---	---
Total		1,807	1.00	---	6,977	401
Quality+	≥270	1,739	0.96	0.03	6,684	408

[a] represents only fish ≥ 240 mm FL

[b] RSD = p' adjusted proportion

Table 10.-Adjusted estimates of age composition and SE and estimated abundance, SE, and CV by age class for Arctic grayling (≥ 240 mm FL), Delta Clearwater River, July 1999.

	Age Composition			Abundance		
Age Class	n	p'[a]	SE[p']	N	SE[N]	CV
3	9	0.02	<0.01	136	28	21%
4	39	0.08	<0.01	570	63	11%
5	118	0.25	0.01	1,760	140	8%
6	136	0.27	0.01	1,872	140	7%
7	82	0.14	<0.01	1,002	80	8%
8	60	0.10	<0.01	675	59	9%
9	39	0.06	<0.01	432	45	10%
10	25	0.04	<0.01	304	39	13%
11	13	0.02	<0.01	132	23	17%
12	6	0.01	<0.01	66	16	25%
13	2	<0.01	<0.01	24	11	44%
Total	529	1.00	---	6,977	401	6%
5+	481	0.90	0.01	6,271	407	6%

[a] p' = estimated adjusted proportion of Arctic grayling at age in the population, weighted by geographic strata.

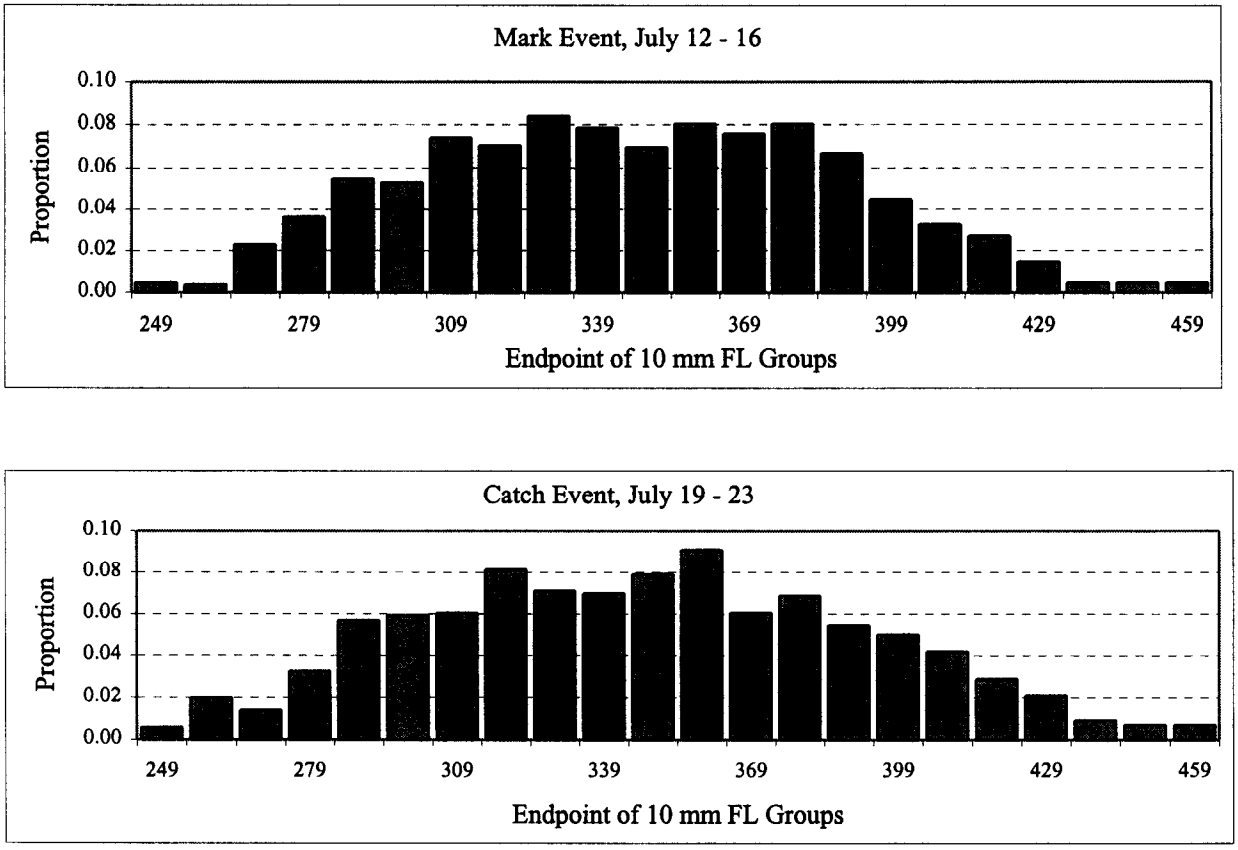
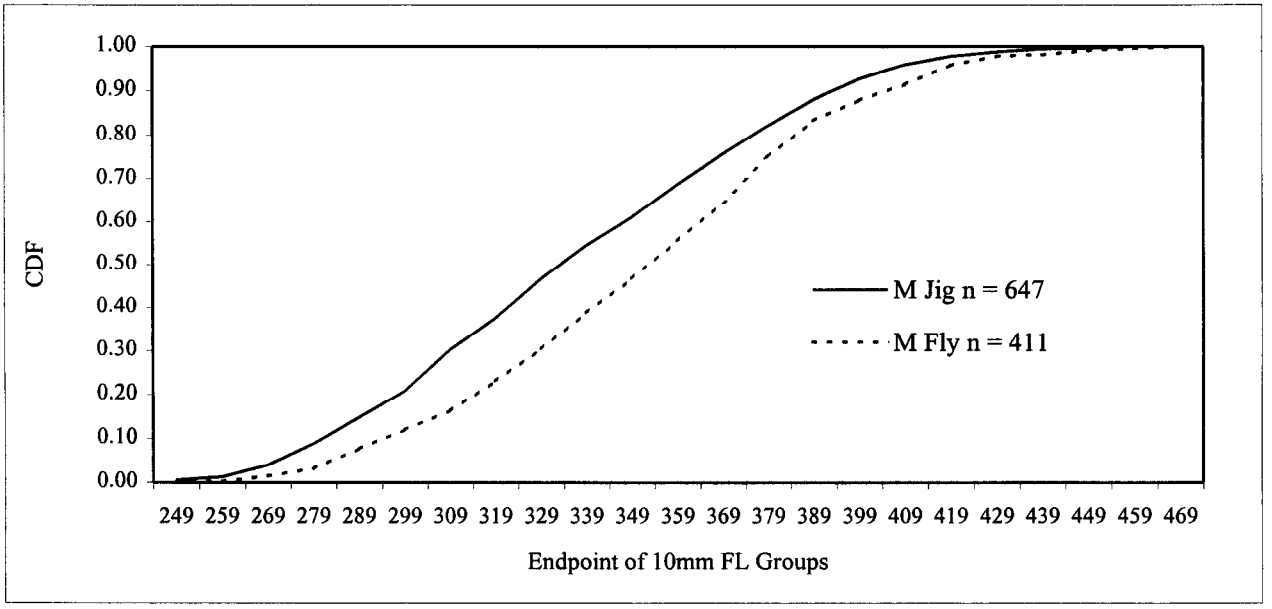


Figure 4.-Length frequencies of Arctic grayling (≥ 240 mm FL) captured in two sampling events, Delta Clearwater River, July 1999.



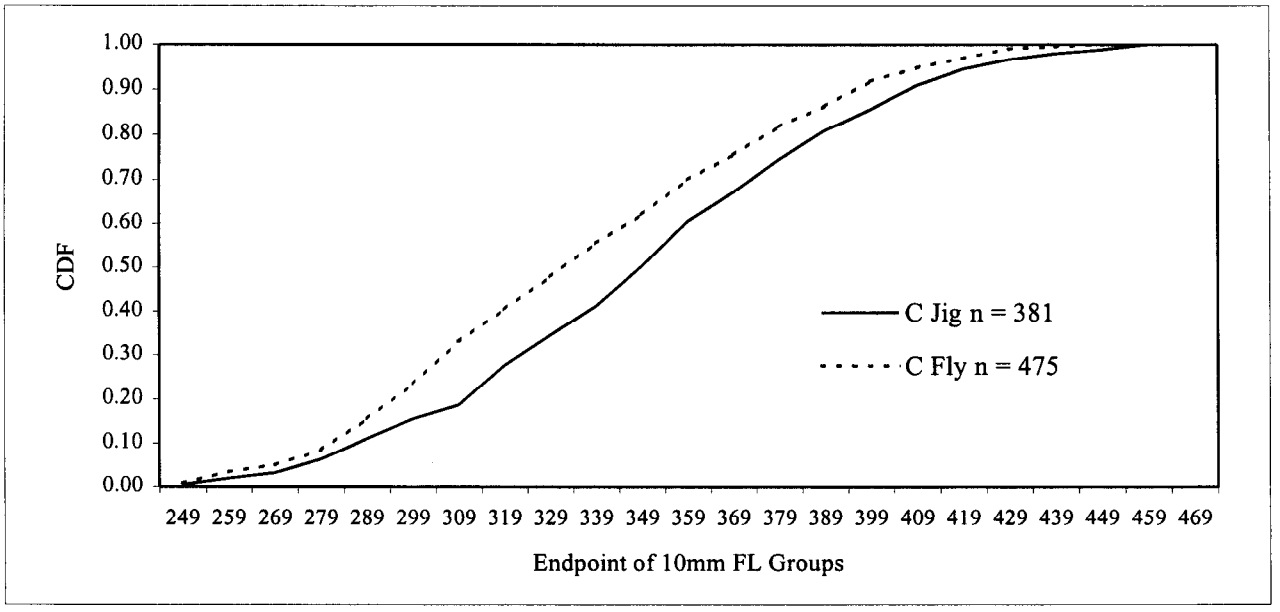


Figure 5.-Cumulative distribution functions (CDF) of 10 mm FL groups of Arctic grayling ≥ 240 mm FL captured by flies and jigs during the first (M) and second (C) events in the Delta Clearwater River, July 1999.

Table 11.-Number of Arctic grayling ≥ 240 mm FL recaptured by location of recapture and location of marking (boundaries of study sections depicted by borders), Delta Clearwater River, July 1999.

	Mile at Recapture													
Mile at Mark	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
7 Days post release														
2	3	1												4
3	1	1	1											3
4	1	1	7	3		1								13
5		1	3	16	2									22
6	1			5	4	1								11
7			1	1		5								7
8				2		1	3	1		1				8
9							1	5				1		7
10									1					1
11							1		2	13				16
12				1							4	1	1	7
13				1				1			2	9	2	15
14													21	21
Total	6	4	12	29	8	8	5	7	3	14	6	11	24	135

throughout the river, mixing crew assignments, and applying the majority of effort during the time of day when fish were most actively feeding.

Hook shyness in the 1999 experiment was examined by comparing differences in rates of recapture between fly- and jig-marked fish. The appearance, use, and manner in which Arctic grayling take flies compared to jigs are distinctly different. Even though the recapture rates of jig- and fly-marked fish were different in the 1998 experiment, they were similar during the 1999 experiment. This may be explained by the behavior of the fish or by the behavior of anglers. When Arctic grayling are not feeding, jigs are more effective in catching fish because of the fish's aggressive behavior towards the jig and the ability of anglers to present jigs to fish that are holding in deep water. Flies are more effective when fish are actively feeding or in shallow water.

Biased estimates result when the marking of fish affects the probability of recapture in the second event. During 1999, the recapture rate of jig-marked fish was less than that of fly-marked fish but was not significantly different as it was in 1998 (Ridder 1999). In 1996 and 1997, gear type was not recorded so the effect of gear shyness was not examined. Since considerably fewer jig-marked fish were released in 1996 and 1997, the gear bias in these years probably had a minimal affect upon the estimates of abundance. To alleviate the possibility of bias, only fly gear should be used during the marking event. Other ways of alleviating the possibility of bias would be to lengthen the hiatus between events.

Most (68%) marked fish that were recaptured were recaptured within the same one-mile sampling area in which they were marked. There were similar movement patterns of jig and fly marked fish. Movement that did occur was predominantly downstream. Emigration out of the study area during the experiment was unlikely because the experiment was during the summer feeding period when Arctic grayling move little. Furthermore, the lower boundary of the study area is a distinct habitat transition, silt laden and inhospitable to feeding. Therefore, there is no concern that the estimate may be biased high due to emigration. Movements within the study area during the summer are not fully understood. If regulations are designed to offer a sanctuary for a portion of the DCR population, movement patterns will need further investigation.

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APPENDIX A. DATA SUMMARIES

Appendix A1.-Summary of Arctic grayling stocked into the Delta Clearwater River, 1974 through 1987.

Year	Brood	Rearing Location	Date	Number	Location	Age	Fish/lb	Weight	Length	Mark	Number
1974	Moose	Hatchery	14-Jun	300,000	Cl Lake	fry	---	---	---	no	---
1975	Moose	Hatchery	26-Jun	100,000	DCR springs	fry	---	---	---	no	---
1975	Moose	ponds	2-Oct	9,100	DCR springs	yearlings	35	---	---	no	---
1976	Moose	ponds	20-Sep	12,096	DCR springs	yearlings	40	---	104	no	---
1977	Moose	ponds	28-Sep	6,684	DCR springs	yearlings	38	---	109	no	---
1977	Moose	ponds	28-Sep	371	DCR	1+	3.6	---	---	no	---
1978	Moose	ponds	21-Sep	6,558	DCR springs	yearlings	33	---	117	no	---
1979	Moose	ponds	26-Sep	651	DCR	1+	2.6	---	247	tag	all
1983	Jack	Hatchery	31-Aug	2,503	DCR springs	yearlings	194	2.3	60	RP	all
1983	Jack	Hatchery	30-Sep	2,983	DCR springs	yearlings	82	5.5	86	RV	all
1983	Moose	ponds	26-Aug	2,189	DCR springs	yearlings	40	11.4	108	Ad/LV	all
1983	Moose	ponds	23-Sep	3,292	DCR springs	yearlings	18	25.3	120	Ad	all
1984	Moose	ponds	8-Jun	1,009	DCR	1+	---	---	170	tag	all
1984	Moose	ponds	21-Sep	122	DCR	1+	2.3	198	232	tag	all
1984	Jack	Hatchery	26-Sep	17,380	DCR springs	yearlings	209	2.2	62	LV	8,038
1985	Moose	ponds	14-Jun	551	DCR	1+	---	---	172	tag	all
1985	Moose	ponds	3-Oct	638	DCR	1+	---	---	211	tag	all
1985	Goodpaster	ponds	1-Oct	12,744	DCR springs	yearlings	41	11.1	103	LP	all
1985	Goodpaster	Hatchery	20-Sep	20,950	DCR springs	yearlings	97	4.7	76	Ad	10,468
1986	Goodpaster	ponds	29-Aug	4,273	DCR springs	yearlings	---	7.3	88	Ad/LV	all
1986	Goodpaster	Hatchery	27-Aug	5,748	DCR springs	yearlings	---	3.7	76	LV	all
1986	Goodpaster	ponds	26-Sep	6,940	DCR springs	yearlings	---	---	---	Ad/RP	all
1986	Goodpaster	ponds	3-Oct	2,928	DCR springs	yearlings	---	---	---	Ad/RP	all

-continued-

Appendix A1.-(Page 2 of 2).

Year	Brood	Rearing Location	Date	Number	Location	Age	Fish/lb	Weight	Length	Mark	Number
1986	Goodpaster	Hatchery	24-Sep	6,016	DCR springs	yearlings	---	7.5	90	RP	all
1987	Goodpaster	ponds	4-Sep	1,310	DCR springs	yearlings	---	---	---	Ad/RV	all
1987	Goodpaster	ponds	4-Sep	35	DCR	1+	---	---	---	tag	all
1987	Goodpaster	Hatchery	28-Aug	5,040	DCR springs	yearlings	105	12.1		RV	all
1987	Goodpaster	ponds	3-Oct	3,442	DCR springs	yearlings	---	---	---	Ad/LV	all
1987	Goodpaster	ponds	3-Oct	54	DCR	1+	---	---	---	tag	all
1987	Goodpaster	Hatchery	7-Oct	5,010	DCR springs	yearlings	77	4	---	LV	all
					Totals						
				400,000		fry					
				164,355		yearlings					
				3,431		1+					
				567,786		Total					

Appendix A2.-Number of angler days, angler hours, unique fish caught, and CPUE of Arctic grayling ≥ 150 mm FL during the mark-recapture experiment by river mile, river section, and event, Delta Clearwater River, July 1999.

Section	River Mile	Angler Days	Angler Hours	Catch	CPUE
		Mark Event, July 12 – 16			
Upstream	14	4	28	62	2.2
	13	6	28.5	100	3.5
	12	2	11.5	108	9.4
	11	6	32	164	5.1
	10	4	27	85	3.1
	9	4	27	45	1.7
Subtotal	---	27	154	564	3.7
Downstream	8	3	17	64	3.8
	7	4	16.3	72	4.4
	6	4	14	31	2.2
	5	4	28	113	4.0
	4	6	25.5	40	1.6
	3	2	16	104	6.5
	2	2	17	96	5.6
Subtotal	---	25	133.8	520	3.9
Mark Total	---	51	287.8	1,084	3.8
		Catch Event, July 19 – 23:			
Upstream	14	4	29.5	59	2.0
	13	6	29	32	1.1
	12	4	18.6	80	4.3
	11	3	12.3	121	9.9
	10	2	15	70	4.7
	9	6	27.5	57	2.1
Subtotal	---	25	131.9	419	3.2
Downstream	8	4	20	57	2.9
	7	6	19.5	68	3.5
	6	3	15	24	1.6
	5	4	23	61	2.7
	4	8	34.5	59	1.7
	3	2	15	93	6.2
	2	4	25	106	4.2
Subtotal	---	31	152	468	3.1
Catch Total	---	56	283.9	887[a]	3.1
Total for Experiment	---	107	571.7	1,971	3.45

[a] Total catch for which location of each capture was identified.

Appendix A3.-Hours fished, catch, and CPUE of Arctic grayling ≥ 150 mm FL by angler during the mark-recapture experiment, Delta Clearwater River, July 1999.

Angler	Hours	Catch	CPUE
1	79	492	6.18
2	62	342	5.53
3	45	202	4.48
4	15	66	4.47
5	57	192	3.37
6	9	27	3.18
7	27	88	3.16
8	26	85	3.07
9	18	52	2.92
10	27	71	2.60
11	32	79	2.53
12	60	142	2.49
13	9	17	2.00
14	29	53	1.86
15	7	12	1.78
16	19	31	1.67
17	33	48	1.48
18	6	8	1.39
19	15	16	1.17
Total	572	2,023	3.46
Average	30	106	2.91
Median	27	66	2.60

Appendix A4.-Summary of Arctic grayling ≥ 240 mm FL caught and recaptured by two gear types, Delta Clearwater River, July 1999.

" i "	C_{1i}[a]	C_{2i}	Recaptures of C_{1i} in C_2 by:		
			Total	Jig	Fly
Jig	647	381	79	42	37
Fly	411	475	53	19	34
Unk	11	23	3	1	2
Total	1,069	879	135	62	73

[a] C_{xi} = Catch in event x by gear type i.

Appendix A5.-Distribution of Arctic grayling ≥ 240 mm FL marked and examined by gear type and river mile, Delta Clearwater River, July 1999.

	Event 1				Event 2			
River Mile	Unk[a]	Fly	Jig	Total	Unk	Fly	Jig	Total
2	0	2	53	55	0	9	45	54
3	0	0	99	99	0	0	32	32
4	3	51	54	108	8	45	26	79
5	1	18	142	161	0	18	103	121
6	0	17	68	85	0	42	28	70
7	0	19	26	45	0	27	30	57
8	4	36	23	63	0	41	16	57
9	0	47	24	71	0	57	10	67
10	0	31	0	31	11	12	1	24
11	3	57	52	112	0	31	30	61
12	0	10	29	39	0	44	14	58
13	0	86	18	104	4	83	6	93
14	4	37	59	96	0	66	40	106
Total	11	411	647	1,069	23	475	381	879

[a] unk = unknown gear type.

Appendix A6.-Age composition and SE and mean length-at-age and SD of all Arctic grayling captured by hook and line, Delta Clearwater River, 19-23 July 1999.

	Age Composition			Length (mm FL)			
Age Class	n	p	SE[p]	Mean	SD	Min	Max
3	11	0.02	0.01	259	20	232	300
4	39	0.07	0.01	287	23	241	338
5	118	0.22	0.02	303	22	250	355
6	136	0.26	0.02	330	24	250	386
7	82	0.16	0.02	352	23	282	402
8	60	0.11	0.01	378	22	320	433
9	39	0.07	0.01	393	20	345	428
10	25	0.05	0.01	406	22	361	454
11	13	0.02	0.01	407	31	345	454
12	6	0.01	<0.01	435	12	421	450
13	2	<0.01	<0.01	426	23	410	454
Totals	531	1.00	---	341	46	232	454

Appendix A7.-Age composition and SE and mean length at age and SD of all Arctic grayling captured by hook and line, Delta Clearwater River, 13-17 July 1998.

	Age Composition			Length (mm FL)			
Age Class	N	p	SE[p]	Mean	SD	Min	Max
2	1	0.00	0.00	196	---	196	196
3	29	0.05	0.01	250	22	209	286
4	93	0.15	0.01	274	23	205	351
5	189	0.30	0.02	304	28	239	379
6	85	0.13	0.01	328	39	250	415
7	94	0.15	0.01	358	32	268	443
8	72	0.11	0.01	369	26	293	422
9	30	0.05	0.01	378	29	308	444
10	17	0.03	0.01	379	29	331	423
11	15	0.02	0.01	395	25	352	435
12	7	0.01	0.00	412	10	395	428
13	6	0.01	0.00	422	27	382	452
14	1	0.00	0.00	406	---	406	406
Totals	639	1.00	---	328	50	196	452

Appendix A8.-Age composition and SE and mean length at age and SD of all Arctic grayling captured by hook and line, Delta Clearwater River, 21-25 July 1997.

Age Class	n	p	SE[p]	mean	std	min	max
1	2	0.00	0.00	146	6	142	150
2	46	0.06	0.01	184	10	158	204
3	109	0.15	0.01	230	18	190	293
4	195	0.27	0.02	279	22	224	353
5	64	0.09	0.01	317	27	259	372
6	139	0.19	0.01	343	22	290	405
7	71	0.10	0.01	358	22	310	405
8	48	0.07	0.01	373	26	312	419
9	21	0.03	0.01	393	24	348	443
10	12	0.02	0.00	399	25	354	445
11	7	0.01	0.00	395	46	304	462
12	1	0.00	0.00	434	---	434	434
13	2	0.00	0.00	431	25	413	449
Totals	717	1.00	---	306	63	142	462

Appendix A9.-Age composition and SE and mean length at age and SD of all Arctic grayling captured by hook and line, Delta Clearwater River, 19-31 July 1996.

	Age Composition			Length (mm FL)			
Age Class	n	p	SE[p]	mean	SD	Min	max
1	1	0.00	0.00	134	---	134	134
2	5	0.01	0.00	191	16	174	210
3	72	0.12	0.01	247	20	208	300
4	51	0.09	0.01	283	20	243	323
5	124	0.21	0.02	313	23	246	382
6	147	0.25	0.02	339	23	291	402
7	87	0.15	0.01	366	23	310	410
8	36	0.06	0.01	382	23	326	426
9	40	0.07	0.01	397	18	354	428
10	15	0.03	0.01	401	19	373	438
11	8	0.01	0.00	421	14	399	439
12	5	0.01	0.00	426	28	391	464
Total	591	1.00	---	334	52	134	464

Appendix A10.-Relative Stock Density (RSD) indices of Arctic grayling (≥ 150 mm FL) captured during mark-recapture experiments, Delta Clearwater River, July 1996 - 1999.

Category	Length (mm FL)	N	RSD	SE[RSD]
		1996		
Stock	150 - 269	96	0.12	0.01
Quality	270 - 339	328	0.41	0.02
Preferred	340 - 449	372	0.47	0.02
Memorable	450 - 559	1	<0.01	<0.01
Trophy	≥560	0	---	---
Total		797	1.00	---
		1997		
Stock	150 - 269	347	0.24	0.01
Quality	270 - 339	557	0.39	0.01
Preferred	340 - 449	528	0.37	0.01
Memorable	450 - 559	1	<0.01	<0.01
Trophy	≥560	0	---	---
Total		1,433	1.00	---
		1998		
Stock	150 - 269	240	0.16	0.01
Quality	270 - 339	681	0.44	0.01
Preferred	340 - 449	616	0.40	0.01
Memorable	450 - 559	5	<0.01	<0.01
Trophy	≥560	0	---	---
Total		1,542	1.00	---
		1999		
Stock	150 - 269	92	0.05	0.01
Quality	270 - 339	812	0.44	0.02
Preferred	340 - 449	915	0.50	0.02
Memorable	450 - 559	12	<0.01	<0.01
Trophy	≥560	0	---	---
Total		1,831	1.00	---

Appendix A11.-Summary of estimates of abundance and SE for Arctic grayling ≥150 mm FL, ≥ 240 mm FL, ≥ 270 mm FL, ≥ age and for recruited fish (age-5), Delta Clearwater River, 1977 - 1999.

									Recruitment	
Year	N[150]	SE[N150]	N[240]	SE[N240]	N[270]	SE[N270]	N[Age 5+][a]	SE[Age 5+]	N[Age 5][a]	SE[Age 5]
1977	nd	---	nd	---	nd	---	9,702	1,234	5,862	1,335
1978	nd	---	nd	---	nd	---	8,826	1,279	4,461	1,484
1979	nd	---	nd	---	nd	---	6,258	885	4,134	1,146
1980	nd	---	nd	---	nd	---	6,175	832	3,467	856
1981	nd	---	nd	---	nd	---	9,829	1,461	6,907	1,640
1982	nd	---	nd	---	nd	---	9,369	1,159	4,554	1,173
1983	nd	---	nd	---	nd	---	12,760	1,746	7,828	1,999
1984	nd	---	nd	---	nd	---	11,063	1,276	4,931	1,295
1985	nd	---	nd	---	nd	---	10,767	1,388	4,458	1,267
1986	nd	---	nd	---	nd	---	7,840	1,148	2,724	708
1987	nd	---	nd	---	nd	---	7,684	1,289	3,571	933
1988	nd	---	nd	---	nd	---	8,845	1,962	1,957	578
1989	nd	---	nd	---	nd	---	6,482	1,751	2,420	601
1990	nd	---	nd	---	nd	---	4,477	1,766	2,301	619
1991	nd	---	nd	---	nd	---	nd	---	1,754	686
1992	nd	---	nd	---	nd	---	nd	---	2,219	1,066
1993	nd	---	nd	---	nd	---	nd	---	945	692
1994	nd	---	nd	---	nd	---	nd	---	1,179	1,491
1995	nd	---	nd	---	nd	---	nd	---	nd	---
1996	nd	---	3,000	370	2,750	340	2,490	310	670	100
1997	9,000	920	7,420	920	6,490	800	4,600	590	810	140
1998	nd	---	5,570	780	4,740	480	4,500	630	1,820	300
1999	nd	---	6,977	401	6,684	211.3	6,271	369	1,760	140
Average	9,000	---	5,742	---	5,166	---	7,663	---	3,217	---

[a] Estimates for 1977 - 1990 are from CAGEAN modeling (Clark and Ridder 1994) and reflect population at start of fishing season. Estimates for 1996 - 1999 are from mark-recapture experiments (Ridder 1998b, Ridder 1999 and this report) and reflect population in July.

nd = no data

APPENDIX B. DATA FILE LISTING

Appendix B1.-Data files[a] for all Arctic grayling captured in the Delta Clearwater River, July 1999.

Data file	Description
U-000600L021999	Sample data from 12-16 July 1999.
U-000600L011999	Sample data from 19-23 July 1999.

[a] Data files are archived at and are available from the Alaska Department of Fish and Game, Sport Fish Division, Research and Technical Services, 333 Raspberry Road, Anchorage, Alaska 99518-1599.

APPENDIX C

Appendix C1.-Data for Darroch model analysis with fly caught marks.

		Recaptures by location (C)		
Mark location	Marks (a)	Lower	Middle	Upper
Lower	423	39	3	0
Middle	295	10	22	2
Upper	351	2	4	53
Catches without marks (b)		234	248	262

Appendix C2.-Darroch model parameter estimates.

Mark Location	Capture Probability	Theta		
		Low	Middle	Upper
Lower	0.098	0.94	0.06	<0.01
Middle	0.12	0.35	0.62	<0.01
Upper	0.18	0.06	0.09	<0.01